

Multiple Electrofishing Removals for Eliminating Rainbow Trout in a Small Southern Appalachian Stream

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Abstract.—We evaluated multiple electrofishing removals of rainbow trout *Oncorhynchus mykiss* as a management tool for the restoration of native brook trout *Salvelinus fontinalis* in a small southern Appalachian stream. Six, three-pass depletion removal efforts were conducted between June 1996 and October 1997. Four removals successfully eliminated rainbow trout reproduction. Five removals were required to successfully eliminate rainbow trout from Mannis Branch. During the study, 428 rainbow trout were removed from the treatment area. The initial removal collected 296 (70%) of the total rainbow trout removed and was dominated by adults. Subsequent removals were dominated by age-0 rainbow trout (57–83%). The initial two removals successfully eliminated 96% of the reproductively mature adults as well as 86% of the age-0 fish. In October 1996, 105 native southern Appalachian brook trout of various age-classes were reintroduced into Mannis Branch. Surveys conducted in May 1997 indicated adult brook trout successfully spawned, initiating repopulation of the treatment area. Multiple removals exhibited no negative population level effects on blacknose dace *Rhynchichthys atratulus* in the treatment area or on rainbow trout in the control stream. Based upon these results, a minimum of three removals conducted per summer should eliminate reproduction and significantly reduce the number of years required to successfully restore a small southern Appalachian stream.

Historically, fishery managers have introduced nonnative fish to accomplish a variety of management goals. These goals include the diversification of sport fishing opportunities, additions to the forage base, and biological control. In many cases, nonnative fishes offered managers an attractive opportunity for providing new game fish that seemed to solve or quickly reverse problems that environmental mismanagement had created (Courtenay and Stauffer 1984). Unfortunately, this “quick fix” was often implemented with little regard for information about the long-term consequences. These actions have resulted in the establishment of nonnative fish populations that cannot be eliminated and have had disastrous impacts on many

native fish communities (Courtenay and Stauffer 1984).

The National Park Service (NPS) is unique among land management agencies in that it is mandated to protect and preserve “naturally functioning ecosystems” (NPS Management Policies 1988). Despite this unique mandate, most parks are faced with many nonnative fish issues. In many cases, the nonnative fish had been introduced into disturbed habitats before acquisition by the NPS. Some park managers continued stocking nonnative fish due to the popularity of fishing, thus insuring the establishment of reproducing populations. In other cases, nonnative sport fish were introduced both intentionally and unintentionally because it was a popular way of diversifying the angling experience. In many cases, these actions were seen as adding to the enjoyment of the park experience and not a violation of NPS policies. Unfortunately, such actions in national parks have resulted in the extirpation of native fish species that are now considered threatened or endangered. Park managers are now faced with developing and implementing native fish restoration programs where feasible.

Population control of nonnative fishes has become an important objective of the NPS in some national parks (Moore et al. 1986; Stevens and Rosenlund 1986). Reclamation efforts in aquatic systems present a dilemma for managers because of difficulties in locating and capturing nonnative species without negatively impacting native species (Moore et al. 1986). Success is also more difficult to judge because of inherent difficulties in determining absolute removal of the introduced species. Traditionally, salmonid restoration techniques in national parks have used chemical or mechanical methods for eliminating nonnative fishes (Stevens and Rosenlund 1986). Western parks typically use chemical renovation techniques (antimycin-A), which have been relatively successful (Stevens and Rosenlund 1986; Rosenlund 1992). Chemical renovation has not been readily accepted in eastern parks primarily because of potential impacts to diverse nongame fish populations, public misconceptions, and previous flawed restoration attempts (Lennon and Parker 1959).

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The decline of native brook trout *Salvelinus fontinalis* in Great Smoky Mountains National Park (GRSM) is well documented (Powers 1929; King 1937; Kelley et al. 1980; Larson and Moore 1985). Since the mid-1970s, park managers have attempted to reclaim carefully selected streams for native brook trout using backpack electrofishing techniques. Studies by Moore et al. (1983), West et al. (1990), Moore and Larson (1989), and Habera et al. (1992) have documented the successes and failures of efforts involving annual removals of rainbow trout in GRSM. Many of the efforts failed due to uncollected fish in areas of complex cover or deep pools (Habera et al. 1992) and the subsequent reproduction of a few remnant fish in these areas (GRSM, unpublished). Carter (1990) removed nonnative rainbow trout twice in one summer and determined this method may be more effective than single annual removals for significantly reducing the number of nonnative salmonids. These findings suggest that multiple removals over successive years may be necessary to eliminate nonnative salmonids.

Brook trout distribution surveys in the 1990s identified several GRSM streams suitable for reclamation efforts. Mannis Branch was identified as an ideal candidate for reclamation by electrofishing because of its small size, the presence of a downstream barrier, the historical presence of brook trout, and accessibility. The objectives of our study were to (1) evaluate multiple electrofishing removals within a year as a tool for the elimination of nonnative salmonids and (2) determine if multiple removals within a year negatively impact nontarget species.

Study Area

We selected two study streams typical of montane, soft water streams throughout GRSM (Table 1). Mannis Branch is a second order tributary of the East Prong of the Little River, a tributary to the Little Tennessee River system (Figure 1). The lower end of the treatment area began at the top of a waterfall (~10 m high) and was 858 m in length. The upper end of the treatment area was marked by a 3-m bedrock cascade that inhibits upstream migration of salmonids. Rainbow trout *Onchorhynchus mykiss* and blacknose dace *Rhinichthys atratulus* were found in the treatment area. No fish were located above the upper cascade. The 858-m treatment area was partitioned into eight 100-m sampling sites and one 58-m site before the first removal.

Blanket Creek (0.8 km upstream of Mannis

TABLE 1.—Physical and chemical stream data collected during brook trout restoration activities on Blanket Creek and Mannis Branch in Great Smoky Mountains National Park (1996–1997). Values shown are means (SE) from samples collected during the course of the treatment period between May 1996 and October of 1997.

Feature	Blanket Creek	Mannis Branch
Water temperature (°C)	14.1 (1.1)	14.2 (0.7)
Conductivity (μS/cm)	10.0 (0.9)	8.9 (0.9)
pH	6.7 (0.2)	6.2 (0.2)
Discharge (m ³ /sec)	0.06 (0.01)	0.03 (0.0)
Wetted stream width (m)	3.6 (0.2)	3.1 (0.1)
Stream gradient (%)	7.6 (0.9)	6.1 (0.5)
Habitat type (%)		
Pool (%)	48	51
Riffle (%)	25	14
Cascade (%)	7	9
Complex (%)	19	26
Substrate (%)		
Cobble	31	36
Small boulder	13	20
Bedrock	23	18

Branch) is a second-order tributary to East Prong of Little River and is open to fish migration from East Prong of Little River (Figure 1). Blanket Creek was used as a control stream for Mannis Branch because of its proximity, similar physical and chemical characteristics (Table 1), and similar fish fauna. Three 100-m sampling sites were randomly selected in Blanket Creek to serve as control sites.

Methods

Rainbow trout removal.—Four rainbow trout removals were conducted on Mannis Branch between June 1, 1996, and August 30, 1996. Two additional removals were conducted on Mannis Branch in May and October 1997. Blanket Creek was sampled within 1 week of each removal of Mannis Branch using the same methods (no sampling was done on Blanket Creek during removal 4). Before each removal, block nets were set at the upper and lower site boundaries to prevent fish movement. Three-pass depletion estimates were conducted on all sites of both streams during each removal. Sampling protocols followed those recommended by the American Fisheries Society, Southern Division, Trout Committee (Trout Committee, American Fisheries Society, unpublished). Backpack electrofishing units similar to those used by Habera et al. (1996) were used during this study at a setting of 600 V AC and an output of 0.22–0.32 A. Electrofishing passes were conducted upstream between site boundaries. Each electrofish-

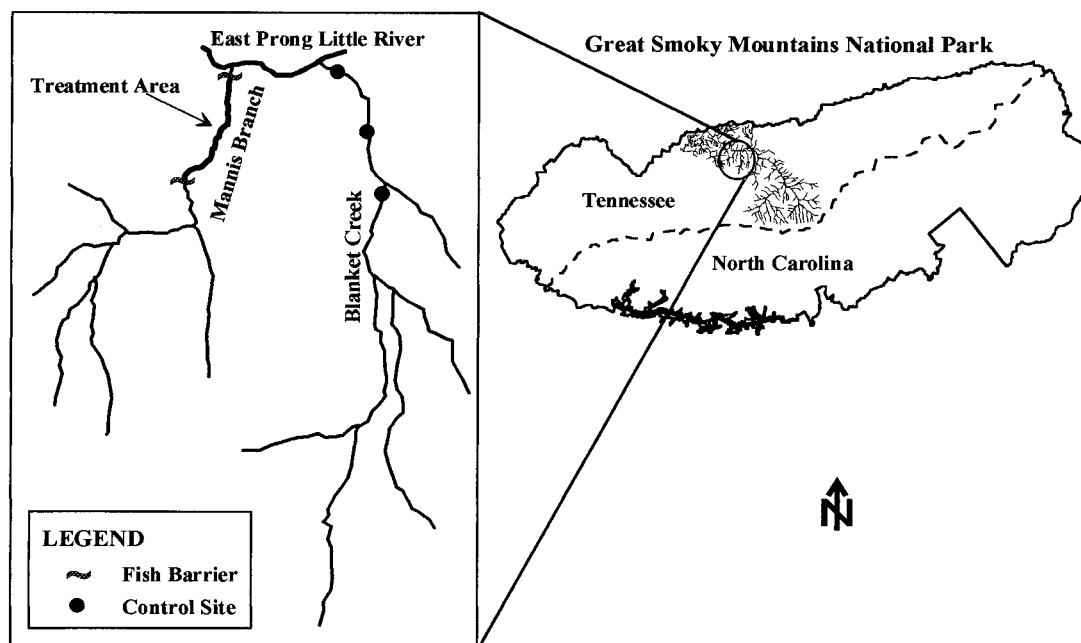


FIGURE 1.—Site map of the rainbow trout treatment area on Mannis Branch and the control sites on Blanket Creek in Great Smoky Mountains National Park.

ing crew contained three people of similar experience and consisted of one person electrofishing, followed by one person with a dip net, and a person with a bucket.

Total length (TL, nearest mm) and weight (nearest 0.1 g) was recorded for each fish after every pass. Rainbow trout and blacknose dace were held in cages outside the section being sampled until sampling was completed. Rainbow trout from Mannis Branch were released into Little River at the end of each removal effort. Blacknose dace were returned to the sections from which they were collected. All fish were returned to the sections from which they were collected in Blanket Creek.

Following removal 4 in October 1996, native southern Appalachian strain brook trout were collected from Indian Camp Creek (50 fish) and Greenbrier Creek (55 fish) in GRSM. These fish were adipose fin clipped, loaded into 5-gal (18.9-L) buckets mounted on backpack frames, and transported to a Tennessee Wildlife Resources Agency (TWRA) hatchery truck. All fish were released alive into the treatment area. Mannis Branch was sampled in May and October 1998 by the methods described above to evaluate the status of the brook trout population.

Population estimates and 95% confidence intervals were generated by site for each removal using

the Microfish 3.0 software (Van Deventer and Platts 1989), which uses the Burnham maximum-likelihood population estimate formula (Van Deventer and Platts 1983).

Results

Rainbow Trout Removal

A data logger error occurred after completion of the first removal effort that eliminated population data for sites 1, 2, and 5 on Mannis Branch. Therefore, a complete set of data existed only for sites 3, 4, 6, 7, 8, and 9. We chose to discuss only data from these six sites for removal patterns and applicability of population estimates.

In all, 428 rainbow trout were removed from the six treatment sites on Mannis Branch during the six removals. Of these, 139 fish (32%) were age 0 (<90 mm) and 289 fish (68%) were adults (>91 mm; Table 2). Adult rainbow trout (79%) dominated the first removal effort; age-0 rainbow trout made up only a small portion (21%) of the catch (Table 2). In subsequent removals, greater numbers of age-0 fish were collected, but adults were scarce. The number of age-0 rainbow trout collected was nearly the same in the first two removals and dominated removal 3, indicating the initial difficulty of collecting the age-0 fish. During the

TABLE 2.—Cumulative catch and density (number of fish/100 m²) for age-0, adult, and total rainbow trout collected during brook trout restoration efforts on Mannis Branch. Parenthetical values are SEs.

Removal number	Catch			Density		
	Age 0	Adult	Total	Age 0	Adult	Total
1	62 (62)	234 (234)	296 (296)	3.3 (1.6)	11.5 (1.6)	14.8 (2.7)
2	58 (101)	43 (277)	101 (397)	2.8 (0.5)	2.1 (0.5)	5.2 (0.7)
3	15 (135)	3 (280)	18 (415)	0.9 (0.3)	0.2 (0.1)	1.1 (0.3)
4	4 (139)	3 (283)	7 (422)	0.2 (0.1)	0.1 (0.1)	0.3 (0.1)
5	0 (139)	6 (289)	6 (428)	0.0 (0.0)	0.4 (0.1)	0.4 (0.1)
6	0 (139)	0 (289)	0 (428)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Total	139	289	428			

first removal, age-0 rainbow trout ranged from 28 to 48 mm. By removal 2, age-0 rainbow trout ranged from 47 to 80 mm and may have been more effectively sampled by electrofishing. The sizes of rainbow trout collected in 1997 (removal 5) indicate they were age-0 fish that were missed in 1996. Rainbow trout reproduction was eliminated in the treatment area following the first summer of removals. All rainbow trout were eliminated from the treatment area after the fifth effort.

The multiple cohorts of brook trout that were reintroduced in 1996 subsequently spawned producing good numbers of age-0 fish. Population sampling in 1997 and 1998 indicate that the brook trout reintroduction efforts were successful. Although the population was still acclimating, brook

trout densities in 1998 (2 years after reintroduction) surpassed pretreatment density levels of rainbow trout.

Effects of Multiple Removals on Dace and Trout

Due to the low number of blacknose dace (<3 per site) in Blanket Creek, comparisons among streams by removal were not performed. Therefore, we focused only on blacknose dace density changes within Mannis Branch. Despite improper handling procedures during the July 1996 sample, which resulted in acute blacknose dace mortality, time series densities showed no population level change during the course of the treatment (Figure 2). Rainbow trout time series densities in Blanket

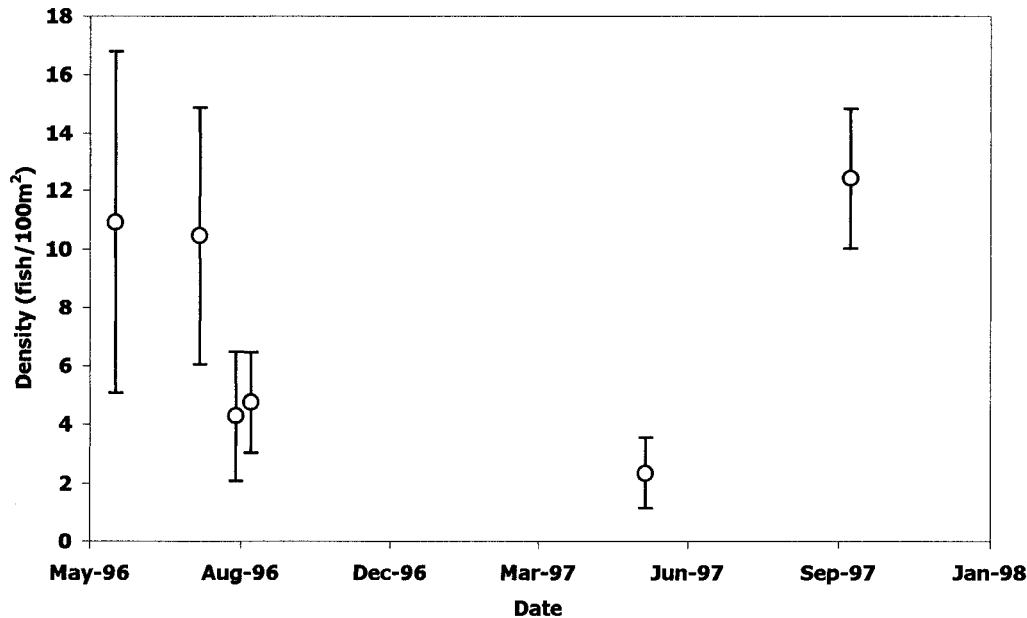


FIGURE 2.—Blacknose dace density (means and SEs) in Mannis Branch during the course of multiple rainbow trout removal efforts.

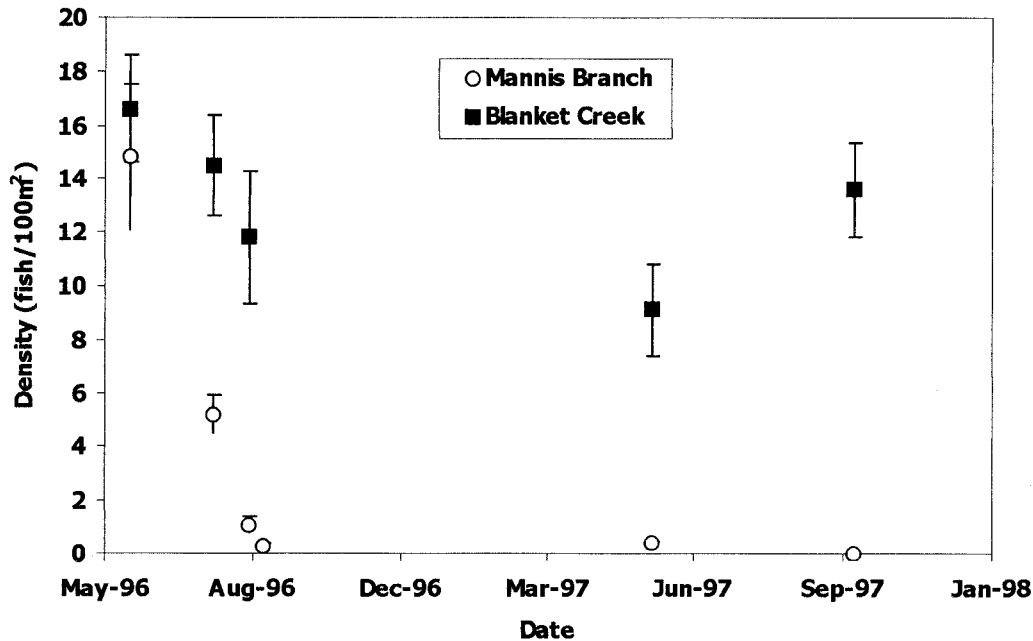


FIGURE 3.—Rainbow trout density (means and SEs) in Blanket Creek and Mannis Branch during the course of rainbow trout removal efforts.

Creek also indicate no population level declines during the treatment period (Figure 3).

Discussion

Mannis Branch offered a unique opportunity to evaluate multiple electrofishing removals in a short segment of a southern Appalachian stream in Great Smoky Mountains National Park. It should be noted that the results from Mannis Branch represent the results from one stream without replication. Despite the lack of replicates, multiple removals proved to be an effective tool to eliminate rainbow trout over a 1-year period. Initial removals focused upon the adults, allowing age-0 rainbow trout to grow throughout the summer and become more susceptible to the gear. Multiple removals apparently eliminated the possibility of rainbow trout reproduction the following spring by reducing fish density to less than 0.4 fish/100 m² throughout the treatment area. Although the initial removal was made 2 months after rainbow trout emergence, they were still difficult to sample in June when they were 28–48 mm long. Future efforts should consider timing the first removal well after emergence, especially in high-elevation areas or in western areas where growth is much slower to ensure thorough removal of age-0 fish.

The value of multiple removals in one summer becomes apparent when compared with the results of annual removal efforts in other park streams. Single three-pass removal efforts were conducted annually in Lost Bottom Creek from 1989 to 1996 (GRSM, unpublished). Removal patterns indicate that even though the number of rainbow trout declined each year, a significant number of older fish remained and reproduced between 1989 and 1994. Rainbow trout were not eradicated from Lost Bottom Creek until reproduction was eliminated in 1995. Successful restoration of two smaller GRSM streams (Moore and Larson 1989) required 3–4 years of annual removals to eliminate reproduction. Once reproduction was eliminated, the complete extirpation of rainbow trout followed within 1–2 years. Similar to the results of previous GRSM studies (Moore and Larson 1986; Moore et al. 1986), Thompson and Rahel (1996) concluded that 42–83% of age-0 brook trout were removed during initial restoration efforts in several Wyoming streams. These studies indicate that initial removals did reduce the numbers of nonnative salmonids, but did not meet the objective of eliminating them.

Size selectivity is also an inherent problem in electrofishing surveys (Junge and Libosvasky 1965; Thompson and Rahel 1996) and has been a major hindrance to previous restoration efforts in

GRSM (Carter 1990; Moore et al. 1981). Several factors determine the efficiency of removal efforts, such as stream cover and habitat complexity (Grant and Noakes 1987; Peterson and Cederholm 1984; Thompson and Rahel 1996), deep water (Riley and Fausch 1992), and size of the fish (Reynolds 1989). One benefit of multiple removal efforts is that the effects of size selectivity on restoration success are ameliorated.

Historically, managers have used either hatchery stocks or collected reared wild fish in the hatchery. Both methods can be costly and labor intensive. Transplanting multiple cohorts into the stream and allowing adults to spawn was an effective and relatively inexpensive means of reestablishment, given limited funding and reasonable accessibility. This technique has been used successfully in other areas of east Tennessee (Holloway 1945; Lennon 1967; Wilkins 1961) and in Wisconsin with brown trout (R. Hunt, Wisconsin Department of Natural Resources, personal communication).

Fisheries managers are typically limited in what they can accomplish within a given year. Most restoration projects are planned for one removal per year simply because of personnel and time limitations. However, data from Mannis Branch indicate that by planning a more intensive initial effort, overall time expenditures may be shortened. The Mannis Branch project took 682 h to treat 858 m of stream (79 h/100 m) over a 1-year period. The Lost Bottom project took 6,715 h to treat 3,800 m of stream (177 h/100 m) over an 8-year period. The initial effort on Mannis Branch took 26 h/100 m, while the final effort took 6 h/100 m. The Lost Bottom project also initially took 26 h/100 m, but the time expenditure only decreased to 19 h/100 m in the last year of the project. By eliminating reproduction in Mannis Branch, the project was completed in 1 year. However, in Lost Bottom Creek, the fish reproduced in five of the first six years, prolonging the eradication of rainbow trout.

Effects of electrofishing and handling stress on nongame fish were initially two major concerns of multiple-removal restoration efforts. These concerns arose from (1) numerous publications that identified significant injuries to salmonids caused by electrofishing (Sharber and Carothers 1988; Hollender and Carline 1994; Meyer and Miller 1990) and (2) possible effects on nontarget species (Barrett and Grossman 1988). Data from Mannis Branch showed no population level declines in blacknose dace populations after six three-pass depletion efforts over an 18-month period. Our field

observations were similar to those of Barrett and Grossman (1988), who indicated that handling stress can be the most important contributor to mortality in nongame species in low-conductivity streams, such as Mannis Branch. The declines observed in blacknose dace in the August 1996 sample (removal 3) were attributed to handling stress incurred during the July 1996 sample (removal 2) when blacknose dace were held in buckets for a period of time while rainbow trout were processed. Improved blacknose dace handling procedures in August limited the amount of acute mortality. Despite the acute mortality we observed, the population quickly reestablished itself through reproduction and recruitment, and we did not observe any long-term change in the population. Therefore, we conclude that multiple electrofishing removals had no negative population level effect on this species.

The study sites on Blanket Creek were not closed to immigration and emigration throughout the study period; however, this was not a major concern given the sedentary nature of adult rainbow trout in southern Appalachian streams (Whitworth and Strange 1983). The rainbow trout population in Blanket Creek exhibited no population level changes even after five sampling exposures in an 18-month period. Habera et al. (1996) found that short-term rainbow trout mortality caused by electrofishing is relatively minimal (<9%) in similar streams in the southern Appalachians and has no population level impact. Similarly on a population scale, brook trout populations in Lost Bottom Creek (GRSM, unpublished) increased annually for 5–6 years until they reached carrying capacity, even though 3.4 km of the stream was intensively electrofished annually for eight consecutive years. Therefore, we conclude that multiple electrofishing removals had no significant negative population level effect on rainbow trout in Blanket Creek.

Management Recommendations

Based upon the Mannis Branch data, a minimum of three, three-pass removals per summer are recommended. Initial removals should be conducted at least 2 months after emergence to maximize capture probability of age-0 fish, with a second and third removal several weeks or a month afterwards. Removals attempted after October would be visually hindered by leaf fall and should be avoided. High-elevation and western areas will need to adjust the timing of removals accordingly to account for emergence and leaf fall. Additional

removals should be completed the second field season based upon the subsequent catch to ensure that no reproduction occurred and to complete the project.

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